Adhesion of cast metal alloy and lithium disilicate copings luted to different core build-up materials with self-adhesive resin cement

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Adhesion of cast metal alloy and lithium disilicate copings luted to different core build-up materials with self-adhesive adhesive resin cement

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Short title: *Adhesion of cast metal alloy and lithium disilicate copings*

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Abstract: This study evaluated the shear bond strength of two coping materials (non-nickel chrome based cast alloy and lithium disilicate ceramic (IPS Empress) to four different core foundation materials (resin composite, cast metal alloy, lithium disilicate and dentin), luted with adhesive resin cement (RelyX Unicem). Specimens (N=56) were fabricated and divided into 8 groups (n=7 per group). Each coping material was luted with self-adhesive resin cement (RelyX Unicem) to the core materials. Bond strength was measured in a Universal Testing Machine (0.5 mm/min). Data were statistically analyzed using a two-way analysis of variance (ANOVA) and Tukey`s HSD tests (alpha=0.05). Both core (p=0.000) and coping material type (p=0.000) significantly affected the mean bond strength (MPa) values. Interaction terms were also significant (p=0.001). The highest bond strength results were obtained when lithium disilicate was bonded to lithium disilicate (21.48) with the resin cement tested. Lithium disilicate in general presented the highest bond results when bonded to all core materials tested (16.55-21.38) except dentin (3.56). Both cast alloy (2.9) and lithium disilicate (3.56) presented the lowest bond results on dentin followed by cast-alloy-cast alloy combination (3.82).

Keywords: Adhesion; cast metal; lithium disilicate; resin cement

Introduction

In most situations, severely compromised teeth due to caries or trauma are restored with complete coverage crowns to restore function and aesthetics in dentistry. In pulpless teeth, the amount of the remaining tooth structure dictates the need and type of core build-up material that serves as a foundation to hold the crown in place. In case of minimal loss of structure, root posts and cores are not necessary [1]. However, when a horizontal loss of the clinical crown is present, resulting from caries, trauma or the previous restoration, a small ferrule can be created in the remaining tooth structure and restored with root post and core build-up with different materials [2-4].

A core build-up should be able to withstand axial and lateral loads and must contribute to the retention and support of both a provisional crown and, in the long term, the definitive extra-coronal restoration where the choice of core material is a crucial factor in the success of the restoration [5]. Core materials used in dentistry have included amalgam, resin composites, glass-ionomers and ceramics [6-13].

Core material type and dentin can affect the adhesion of crown materials cemented with luting cement to these substrates. The clinical success of dental restorations is profoundly dependent on the luting cement and the cementation procedures [14]. Dental luting agents should both increase retention of the restoration and maintain its integrity on the dental tissues. In recent years, resin cements have gained popularity because of their advanced physical properties, high mechanical strength and chemical adherence to tooth substance, resin composites as well as ceramics [15]. Adhesive properties of cements are significantly important for the stability of restorative materials, especially for teeth with limited retention. Therefore, it is essential to achieve adequate bond of the resin cement to the restorative, core material and the dentin. Selection of core and coping materials depends on the needs for strength, biocompatibility and aesthetics [16]. To the best of the authors' knowledge, no study addressed the adhesion between different core and crown materials luted with adhesive resin cement.

The objective of this study therefore was to evaluate the adhesion of two coping materials (cast metal alloy and lithium disilicate ceramic to four different core foundation materials (resin composite, cast metal alloy, lithium disilicate ceramic and dentin), luted with self-adhesive resin cement. The null hypothesis tested was that neither the crown nor core material would significantly affect the adhesion results.

Materials and Methods

Specimens (N=56) were fabricated and divided into 8 groups consisting of 7 specimens each with different core and coping material combinations (Table 1).

Preparation of core materials

A silicon mould (Aquasil Ultra LV, Dentsply, Milford, DE, USA) (diameter: 10 mm, height: 3 mm) was made to fabricate the cores made of resin composite, cast metal and all ceramic.

Resin composite group

Resin based core build-up material (Multicore, Ivoclar Vivadent, Schaan, Liechtenstein) was injected directly from the syringe tip into the cavity of the silicon mould. A glass slab was placed on the top and bottom of the mould and the resin was photo-polymerized (XL 2500, 3M ESPE, St. Paul, MN, USA) for 40 s.

Cast metal alloy group

Blue inlay wax (Ivoclar Vivadent, NY, USA) was melted and poured in the silicon mould and left to set for 1 hour for further processing. The resultant disc of wax was connected to a wax sprue (Bego, Bremer Goldschlägerei Wilh. Herbst GmbH Co. KG, Bremen, Germany) and invested in a phosphate-bonded investment (Multi-Vest, Dentsply International, York, PA, USA) mixed under vacuum for 1 minute. After 1 hour setting time, the specimens were placed in an oven for burn out (Accu-Therm II 250, Heraeus Kulzer, South Bend, IN, USA) and gradually heated up to 800ºC. All specimens were cast at (950-1000ºC) in a centrifugal casting machine (74 Exact-U-Cast, Handler, Westfield, NJ, USA) using non-precious nickel chrome based metal alloy (Vera Bond II, Aalba Dent, Fairfield, CA, USA), divested and airborne-particle abraded (Miniblaster, Belle de St. Claire, Encino, CA, USA) using 50 µm aluminum oxide (Strahlmittel, abrasives, Renfert GmbH, Hilzingen, Germany) at 60 psi (Easy Blast, Bego, Bremen, Germany) for 15 s in order to remove the residual investment material. The sprues were cut off with metal discs (Dentarium International Inc., New York, NY, USA) and were finished using diamond bur (3069 diamond bur, KG Sorensen, Sao Paulo, Brazil).

Lithium disilicate group

Wax patterns were invested (IPS Empress Investment, Ivoclar Vivadent) and heat pressed using lost wax technique. After the burn out and preheating process, the core material (Empress-Cosmo, Ivoclar Vivadent, Lot no: D64021) was pressed at 900°C at 5 bar pressure. The core discs were divested and specimen surfaces were carefully airborne-particle abraded (Miniblaster) using 50 µm aluminum oxide particles at a pressure of 80 psi.

Dentin group

After removal of debris, human sound extracted premolars were sectioned 2 mm coronal to the most incisal point of the cemento-enamel junction (CEJ) with a low speed diamond saw (Isomet 2000, Buehler Ltd, Lake Bluff, NY) under copious water cooling. Buccal enamel surfaces of all teeth were totally removed perpendicular to the long axis of the tooth using water-cooled cylindrical diamond (#837-016, SSwhite, USA). Then, the dentin surfaces were prepared with 240, 400, and 600 grit silicon carbide papers (Matador, Germany) in sequence under copious water.

Finally, the specimens were mounted in auto-polymerizing resin (Ortho Resin, Dentsply DeTrey Gmbh, Konstanz, Germany) in polyvinyl chloride moulds (diameter: 18 mm; height: 25 mm) with their cementation surfaces exposed.

Preparation of coping materials

Cast metal alloy

Bar-shaped wax (Gebdi Dental Products GmbH, Engen, Germany) (diameter: 4 mm; thickness: 5 mm) specimens were connected to a wax sprue (Bego, Bremer Goldschlägerei Wilh. Herbst GmbH Co. KG), and invested in a phosphate-bonded investment material (Multi-Vest, Dentsply International, York, PA, USA) that was mixed under vacuum for 1 minute. After 1 hour setting time, the specimens were placed in the oven (Accu-Therm II 250) for burn out and gradually heated up to 800ºC. All specimens were cast at (950-1000ºC) in a centrifugal casting machine (74 Exact-U-Cast, Handler, Westfield, NJ) using non-precious nickel chrome based metal alloy (Vera Bond II, Aalba Dent, Fairfield, CA, USA). Then, specimens were divested and airborne-particle abraded (Miniblaster, Belle de St. Claire) using 50 µm aluminum oxide (Strahlmittel abrasives, Renfert GmbH) at 60 psi (Easy Blast, Bego, Bremen, Germany) for 15 s in order to remove the residual investment material. The sprues were cut off with metal discs (Dentarium International Inc., New York, NY, USA) and were finished using diamond bur (3069 diamond bur, KG Sorensen, Sao Paulo, Brazil).

Lithium disilicate group

The specimens in this group were prepared using the identical protocol described for lithium disilicate group described under core materials.

Cementation

Lithium disilicate specimens were etched using hydrofluoric acid (Ultradent Products, Inc, South Jordan, UT, USA) for 1 minute, washed and rinsed thoroughly.

Each coping specimen was luted to the corresponding core specimen using self-adhesive resin cement (RelyX Unicem, 3M ESPE, St. Paul, MN, USA) according to the manufacturer’s instructions. The cement capsule was activated for 2 s and mixed automatically in a high-speed mixed (Ultramet 2, SDI Limited, Bayswater, Victoria, Australia) for 10 s. Thereafter, resin cement was applied on the coping surface and placed on the core surface under finger pressure. Excess cement was removed from the core surface using microbrush. Bonded core-coping assemblies were photo-polymerized from a distance of 3 mm using halogen polymerizing unit (Astralis 10, Ivoclar Vivadent) at 750 mW/cm^2 for 40 s from 4 directions each.

Specimens were stored in water at 37°C for 24 h prior to tests.

Bond strength test

Shear bond strength testing was carried out in Universal Testing Machine (Instron, Model 8500 Plus Dynamic Testing System, Instron Corp., High Wycombe, UK) at a cross-head speed of 0.5 mm/min. Bonded core-coping interfaces were loaded axially until debonding.

Statistical analysis

Data were analyzed using a statistical software package (SPSS Software V.16, Chicago, IL, USA). Kolmogorov-Smirnov and Shapiro-Wilk tests were used to test normal distribution of the data. As the data were normally distributed, 2-way analysis of variance (ANOVA) was used where bond strength (MPa) was the dependant variable and coping materials (2 levels: cast metal alloy and lithium disilicate ceramic) and core materials (4 levels: resin composite, cast metal alloy, lithium disilicate and dentin) as the independent factors. Multiple comparisons were made using Tukey`s test. $P<0.05$ was considered to be statistically significant in all tests.

Results

Both core (p=0.000) and coping material type (p=0.000) significantly affected the mean bond strength (MPa) values. Interaction terms were also significant (p=0.001) (Table 2).

Within the metal coping groups, significant differences were observed when bonded to metal, composite (p=0.010) and lithium disilicate core materials (p=0.026) (Table 3).

While composite and dentin core materials showed significant difference for both metal (p=0.003) and lithium disilicate coping materials (p=0.007), no significant difference was observed between the metal and dentin core materials (p=0.945) and between lithium disilicate and resin composite core materials (p=0.978).

For the dentin core groups, there was no significant difference in the mean bond strength between the metal and lithium disilicate coping materials (p=0.538).

The highest bond strength results were obtained when lithium disilicate was bonded to lithium disilicate (21.48) with the resin cement tested. Lithium disilicate in general presented the highest bond results when bonded to all core materials tested (16.55-21.38) except dentin (3.56). Both cast alloy (2.9) and lithium disilicate (3.56) presented the lowest bond results on dentin followed by cast-alloy-cast alloy combination (3.82).

Discussion

The type of core build-up, cement material and core materials affects the survival of extracoronal restorations. This study was undertaken to evaluate the adhesion of two coping materials (cast metal alloy and lithium disilicate ceramic to four different core foundation materials (resin composite, cast metal alloy, lithium disilicate ceramic and dentin), luted with self-adhesive resin cement. Based on the results of this study, since both core and coping material types significantly affected the bond strength values, the null hypothesis could be rejected.

Within the metal, composite, and lithium disilicate core groups, the results showed significant differences in the mean bond strength when using the metal and lithium disilicate coping materials. However, for the dentin core groups, there was no significant difference between both coping materials. In the present study, self-adhesive resin cement (RelyX Unicem) was used. Self-adhesive cements principally do not require any surface conditioning method such as etching, priming or bonding. Hence they could be used as conventional luting cements on different types of prosthetic core materials [17]. Although, the manufacturer`s recommendations of RelyX Unicem do not recommend surface any surface conditioning method prior to the application of the cement, lithium disilicate ceramic specimens were etched with hydrofluoric acid for 1 minute. Previous studies either used hydrofluoric etching and silanization [18] or not [19]. Although controversial protocols are presented in these studies for self-etching luting cements, etching the intaglio surfaces of glassy matrix ceramics and bonding with resin cement increases the flexural strength of such ceramics [20]. The high results obtained with the ceramic group in this study on metal, composite and lithium disilicate cores could evidently be explained by the micromechanical retention created after hydrofluoric acid etching. It also has to be noted that no silane coupling agent was used after hydrofluoric acid etching. Likewise, no alloy primers were used for conditioning cast alloy surfaces after air-abrasion. Hence, the chemical component was absent in adhesion of the resin cement to the substrates.

The other reason for high bond results in the lithium disilicate group could be due to better light transmission through this material compared to cast metal alloy that might have increased polymerization. Yet, apparently, photo-polymerization alone was not sufficient for increasing adhesion on dentin since also in the ceramic group, adhesion to dentin was weak. The reason for this is that the self-adhesive cements do not etch the dentin at the same level as phosphoric acid etching as they usually contain acidic monomers such as phosphoric acid esters, MDP, bis-HEMA-phosphate, glycerolphosphate dimethacrylate, 4-META, others contain bis-GMA alone or in combination with TEG-DMA with low pH [21,22].

In this study, the highest mean bond strength value was recorded for lithium disilicate coping group (21.5 MPa) was less than previous studies where values in the range of 23-41 MPa [23] and 23-41 MPa [24] were reported. Nevertheless, the presence of macromechanical retention may offset the adhesion related problems in retention of copings on core materials [25]. Considering that the patients function, immediately after cementation of the restorations, this study assessed immediate bond strength between the self-adhesive resin cement and restorative materials. Further studies should also look at durability of adhesion results obtained in this study after long-term aging on a larger sample.

Conclusions

From this study, the following could be concluded:

1. Lithium disilicate coping material bonded to the same core material demonstrated the highest bond strength with the self-adhesive resin cement tested.
2. Lithium disilicate and cast alloy coping material showed the lowest results when bonded to dentin, followed by cast alloy coping bonded to cast alloy.
3. On all core materials tested, cast alloy coping delivered lower bond strength compared to lithium disilicate.

Clinical Relevance

When self-adhesive resin cement (RelyX Unicem) is chosen for luting coping material to core material, the choice of material should be lithium disilicate for both the coping and the core, which should be etched with hydrofluoric acid for 1 min prior to bonding. RelyX Unicem cannot be indicated for bonding coping materials on dentin due to low bond strengths obtained.

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C**onflict of interest**

The authors did not have any commercial interest in any of the materials used in this study.

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Captions to tables:

Tables:

Table 1. Distribution of core and coping materials composing the experimental groups.

Table 2. Results of two-way ANOVA and Tukey`s tests.

Table 3. The mean and standard deviations of shear bond strength of the experimental groups. *Same lower case superscript letters indicate no significant difference for cast alloy and same upper case superscript letters indicate no significant difference for lithium disilicate copings bonded on different core materials ($p>0.05$).

Tables:

Core Material	Coping Material	Group Numbers
Resin composite	Lithium disilicate	1
Resin composite	Cast alloy	2
Dentin	Lithium disilicate	3
Dentin	Cast alloy	4
Lithium disilicate	Lithium disilicate	5
Lithium disilicate	Cast alloy	6
Cast alloy	Lithium disilicate	7
Cast alloy	Cast alloy	8

Tables:

Table 1. Distribution of core and coping materials composing the experimental groups.

Source	Type III Sum of Squares	df	Mean Square	F- value	P- Vaue
Core	1245.222	3	415.074	22.956	0.000
Coping	1089.376	1	1089.376	60.248	0.000
Core x Coping	336.344	3	112.115	6.200	0.001
Error	867.919	48	18.082		
Total	9970.862	56			
Corrected Total	3538.861	55			

Table 2. Results of two-way ANOVA and Tukey`s tests.

Core	Coping	Mean (MPa)	N
Cast alloy	Cast alloy	3.82±0.8^{a}	7
	Lithium disilicate	16.55±4.9^{A}	7
Resin composite	Cast alloy	9.59±3.9^{b}	7
	Lithium disilicate	18.92±3.3^{A}	7
Lithium disilicate	Cast alloy	8.92±4.6^{b}	7
	Lithium disilicate	21.48±8.1^{A,B}	7
Dentin	Cast alloy	2.9±1.4^{a}	7
	Lithium disilicate	3.56±2.4^{C}	7
Total	Cast alloy	6.31±4.2*	28
	Lithium disilicate	15.13±8.5**	28
	Total	10.72±8	56

Table 3. The mean and standard deviations of shear bond strength of the experimental groups. *Same lower case superscript letters indicate no significant difference for cast alloy and same upper case superscript letters indicate no significant difference for lithium disilicate copings bonded on different core materials (p>0.05).